Model atmospheres for K-giants

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Abstract. In this paper I describe a software package that may be used to determine basic parameters of atmospheres of K-giants, e.g. $T_{\rm eff}$, $\log g$, $[Fe/H]$ and $v_{\rm turb}$. A model atmosphere computed by ATLAS9 is used to calculate synthetic spectrum by program SYNSPEC36. Parameters used for computing model and synthetic spectrum are optimized to match the observed spectrum. This package is used for determining the parameters of atmosphere of α Cas.

Key words: methods: data analysis – stars: abundances – stars: late type – stars: atmospheres

1. Introduction

One of the most powerful methods for determining the parameters of stellar atmospheres ($T_{\rm eff}$, $\log g$, [Fe/H], $v_{\rm turb}$ and $v \sin i$) is direct comparison of computed (synthetic) and observed spectrums. A nonlinear least squares algorithm must be used for minimizating the difference between observed and synthetic spectra. In this paper is described a package of computer programs, which has been used for determining the basics parameters of atmosphere of cool giant α Cas.

The calculation of the synthetic spectra we can divide into following steps:

1. The calculation of model atmosphere
2. The calculation of synthetic spectrum

For computing models atmospheres of K-giants I use program ATLAS9 (Kurucz, 1992), for computing spectra program SYNSPEC36 (Hubený, Lanz, 1995).

2. Model atmosphere

For computing a model atmosphere I use Kurucz program ATLAS9 (Kurucz, 1992) adopted for SunOS by Lemke (Lemke, 1995).

Program ATLAS9 uses this basic astrophysical and numerical assumptions:

- Atmosphere consists of plane-parallel layers in radiative and hydrostatic equilibrium.
- The satisfactory of local thermodynamical equilibrium (LTE). Unfortunately NLTE models for cool stars are not yet available, but NLTE effect doesn't play an important role in atmospheres of late-type stars.
- Inclusion of opacity by opacity distribution functions (ODF). In this ODFs is included about 58 millions of atomic and molecular lines. This is important mainly for cool stars.
- Inclusion of convection by mixing-length theory. According to numerical simulation of stellar convection (Abbett et all, 1997) I have chosen $l/H = 1.5$.

Figure 1 shows comparison between models computed by ATLAS9 with older models published by Bell et all, 1976. Differences detected in deeper atmospherical layers are probably induced by better inclusion of atomic and molecular lines by Kurucz.

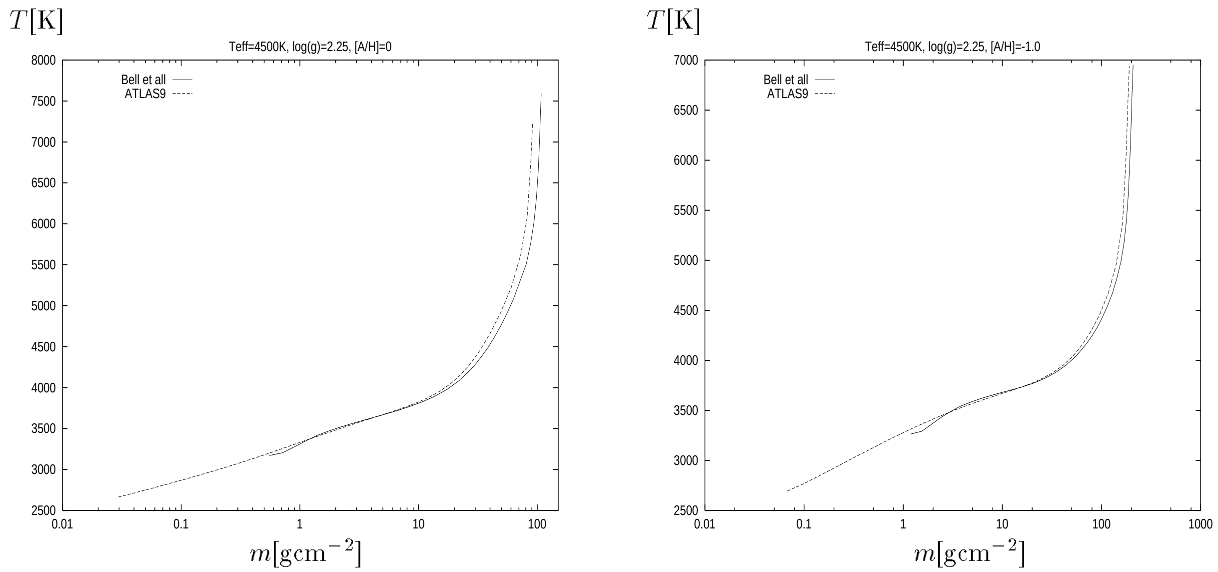

Figure 1. Comparison between model ATLAS9 and Bell et all

3. Synthetic spectrum

The synthetic spectrum is calculated by program SYNSPEC36. This program solves for given wavelengths an equation of radiative transfer. I enlarged the number of considered atoms. The original version allowed to include only atoms with $Z \leq 30$ and I included atoms with $Z > 30$.

The oscillator strengths used for computation I take from Vienna Atomic Line Database (VALD, Piskunov et all, 1995). The rotational and instrumental profile calculates program ROTIN3, distributed with SYNSPEC36.

4. The optimization of parameters of stellar spectrum

As the optimization criteria I have chosen least squares method. The synthetic spectrum is spline interpolated to the same wavelenght scale as the observed spectrum. In this points program computes squares of differences of observed and synthetic spectrum and the squares are summed for all wavelength points. The result is used as optimization criteria.

The optimization consists of three steps:

1. optimization $v \sin i$ and a parameter λ_{inst}, which describes full width at the half maximum of the gaussanian instrumental profile.

2. optimization of [Fe/H], v_{turb}

3. optimization of T_{eff}, $\log g$.

Described steps are repeated till the given convergence criteria is satisfied. In steps 1. and 2. is used variable metric method, in step 3. simplex method due the problems with computing of gradient.

The reason for choosing a three-steps optimizations is a decrease of computer time because the most time spending procedure is computing of model atmosphere.

5. The processing of spectrum of α Cas

Presented computer package I used for determining the parameters of K-giant spectral type K0 IIIa α Cas. The used spectra were completely described by Štefl, 1985, 1993. Due to the problems with the rectification of the used photographic spectrum I have chosen several intervals for optimization procedure. The results are compiled in 1. The available values of these parameters are given in table 2.

Interval [nm]	T_{eff} [K]	$\log g$	[Fe/H]	v_{turb}[kms^{-1}]
601.0 – 601.5	3980	2.1	0.00	2.6
602.0 – 602.8	4140	2.0	-0.19	4.0
609.4 – 610.0	4420	1.6	-0.16	3.9
613.3 – 613.9	4400	2.4	-0.14	1.5

Table 1. The results of minimization in given intervals

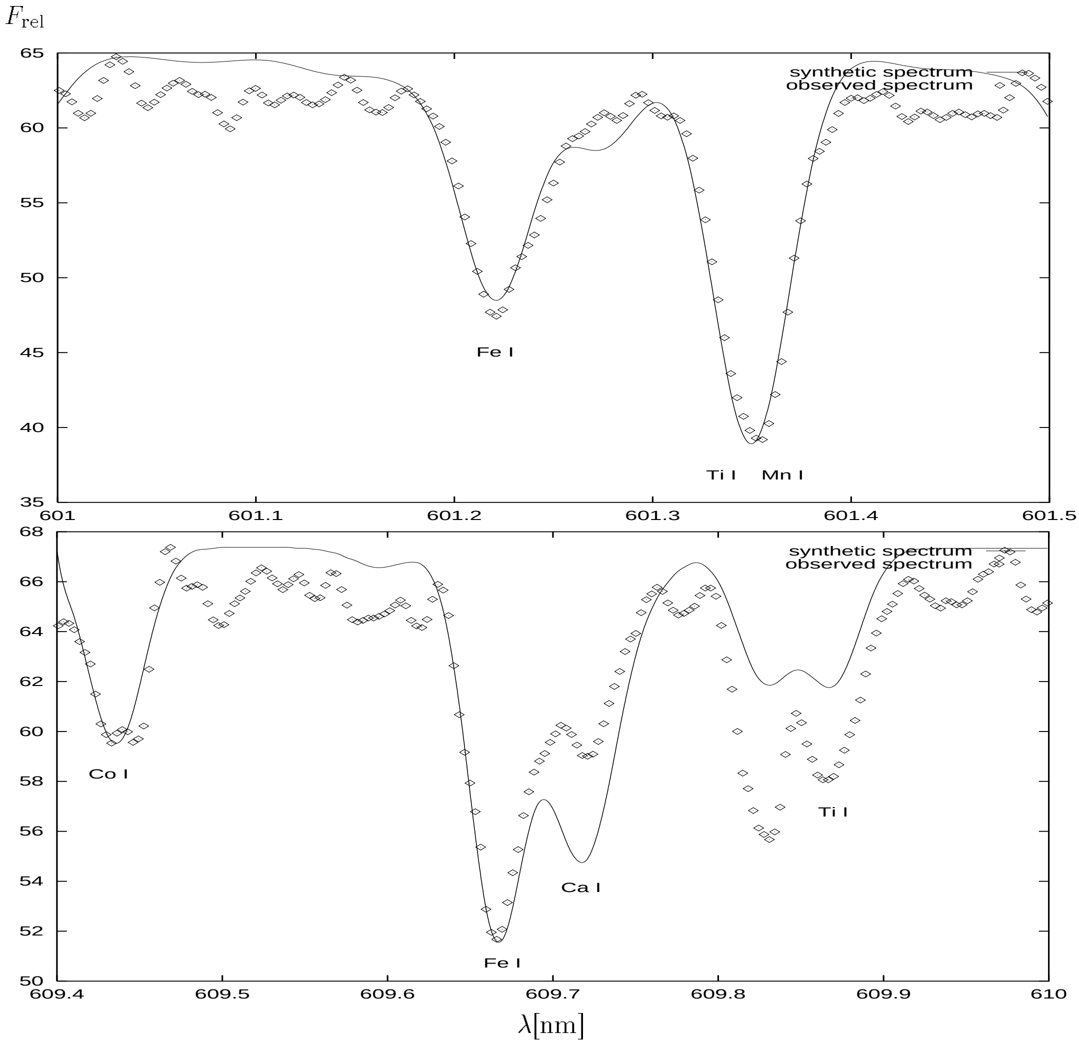

Figure 2. The results of minimizations in the given wavelength interval

The rate of the convergence was rather fast. Steps No. 1. and 2. are repeated usually to achieve a convergence of basic parameters at a value about 10^{-4}. The step No. 3 is repeated usually 2-3 times to achieve the same convergence.

The problem of unknown instrumental profile influenced the quality of given results. But the resulting abundance and gravitational acceleration are fully reflectable. This problem will be discussed in my diploma work.

Quantity	Literature				
	Stefl 1993	Lambert, Ries 1981	Gratton et all 1982	McWilliam 1990	this work
$T_{\rm eff}$ [K]	4520	4760	4710	4610	4240 ± 130
$\log g$	–	2.0	1.1	2.7	2.0 ± 0.2
[Fe/H]	-0.22	-0.18	-0.03	-0.09	-0.12 ± 0.05

Table 2. Comparison of given parameters ofα Cas

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